International Journal of Geology, Agriculture and Environmental Sciences
Volume – 3 Issue – 4 August 2015
Website: www.woarjournals.org/IJGAES *ISSN: 2348-0254*

Toxicity of Heavy Metals and Effect of their Concentrations on Biological Productivity and Diversity in Freshwater Ecosystem

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Abstract: ***Toxicity of copper (Cu), iron (Fe) and lead (Pb) to tilapia fish was determined using the simple arithmetic graphic method. In each experiment, a control (distilled water) and graded concentrations of the test metals were used. Observations for fish mortality and subsequent removal of dead fishes were made hourly for 4 days. Percent mortality was calculated for each of the heavy metals and 96-hr LC_{50} for Cu, Fe and Pb for tilapia fish were determined to be 0.44 mg/l, 0.96 mg/l and 2.85 mg/l, respectively. Of interest was the result obtained on biological productivity in the aquarium containing 2.85mg/l of Pb within seven (7) days from the start of the experiment. Biological productivity and thus high diversity were observed in the case of Cu and Fe when the period was lengthened to fourteen (14) days. As against scientific believe that Pb is highly toxic to humans, this study showed that Pb pollution in a freshwater ecosystem encourages high rate of biological productivity and thus high diversity; thus confirming that heavy metals have differing effects on biological productivity and diversity in the ecosystem. Lead (Pb), whose response is dictated by the dose which may depend on mobility and bioavailability, was therefore identified by this work as a trigger factor to eutrophication.***

Keywords: Heavy metal, toxicity, biological productivity, ecosystem.

1. Introduction

Modern technology uses heavy metals both in the elemental and combined forms [1]. During recent years serious concern has been voiced about the deteriorating state of fresh water bodies with respect to trace metal pollution. Heavy metals have the potential to be toxic to living organisms, if present at a level above a threshold. The metal concentrations are routinely monitored using biomonitoring species, which accumulate heavy metals in their tissues and may therefore be analyzed as a measure of the bioavaliability of metals in the ambient habitat [2]. Low salinity which is unique to fresh water systems is known to increase the bioavalabilities of metals [3] and this may increase metal bioavailabilities at sites with low metal concentrations. Changes in pH can induce significant effects on the partitioning of metals between dissolved and particulate phases as well as on their speciation in each of these phases [4].

It is recognized that in freshwater systems trace metals have high pollution potential that could be measured through the use of fish [5]. A number of human activities have been identified through research to impact on biological productivity in fresh water ecosystems either positively or negatively [6]. Some of such activities include dredging, petroleum exploration and production, road and bridge construction, urbanization, indiscriminate use of fertilizers and pesticides on agricultural lands, industrialization, indiscriminate waste dumping and filling of wetlands, amongst others. According to Oribhabor [7], human activities have great impacts on biodiversity in the Nigerian aquatic ecosystems. His work revealed that the impact can be brought about through persistent threat by heavy metals and eutrophication, amongst others. The work of Moslem and Miebake [8] on the effect of dredging on plankton community of Orashi River in the Niger delta, Nigeria showed that nutrient levels downstream of the dredger position had higher influence on the plankton community than the dredging induced-increase in turbidity and total suspended solids.

This present research on the toxicity of heavy metals and effect of their concentrations on biological productivity and diversity in freshwater ecosystem was designed using three heavy metals (Cu, Fe, Pb) separately, to show the effect of these metals on biological productivity in a static simulated study.

2. Materials and Methods

2.1 Mortality Studies

Preliminary tests to determine the survivability of *tilapia guinensis* in graded concentrations of the same heavy metal solutions were carried out. Copper (Cu), iron (Fe) and lead (Pb) solutions were used. Mortality of fishes with time was determined for each of the heavy metal concentrations and control. In each test, 10 fish samples were exposed in a tank containing 20L of test solutions with different concentrations of the heavy metals. The control did not contain any trace of the heavy metals. Observations for mortality were made hourly at regular intervals. Dead fishes were removed at each observation and percent mortality was calculated for the heavy metal concentrations selected for the mortality studies. This was repeated for each of the heavy metals. The test lasted for 96 hrs. From the observations made, it was possible to select four concentrations for the heavy metal toxicity studies.

2.2 Toxicity Studies

Aerated aquaria used in this Lethality studies were similar to those described by Ahsannulah et al [9]. All tests were static and were conducted in accordance with the recommendations of Spraque [10]. In each experiment, a control (distilled water) and selected graded concentrations of the test heavy metals (Cu, Fe and Pb) were used. Four different concentrations were selected for the toxicity studies and *tilapia guinensis* were exposed to these test solutions. Ten (10) fishes were kept in each aquarium containing 20L of test solution. The test lasted for 96 hours. Curves of percent mortality against concentrations were plotted and the LC_{50} of each of the heavy metals under study were derived from the toxicity curves.

2.3 Biological Productivity

Selected solutions of the Cu, Fe and Pb heavy metals were used in static simulation studies. Mortality and toxicity studies were each carried out for 96 hours. The period for the toxicity studies was extended to 168 hours (7 days). Test solutions were observed for any effect due to the heavy metals in solution. The test was also extended for 14 days for observed effects to be more obvious.

3. Results and Discussion

3.1 Mortality Studies

The results obtained for percent mortality of fish in the different tested heavy metal solutions are shown in figures I-III. It was generally observed that mortality was increased as the concentrations of the different heavy metals were also increased.

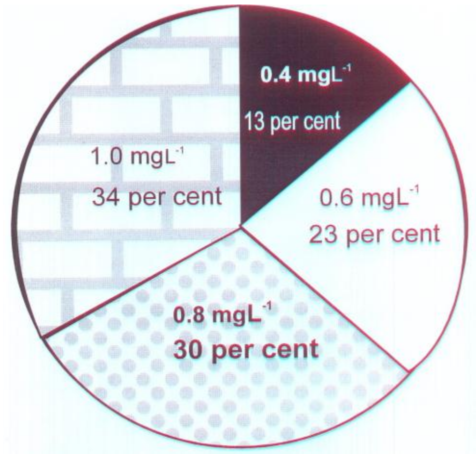

Figure 1: Percent mortality of fish in Copper (Cu) solution

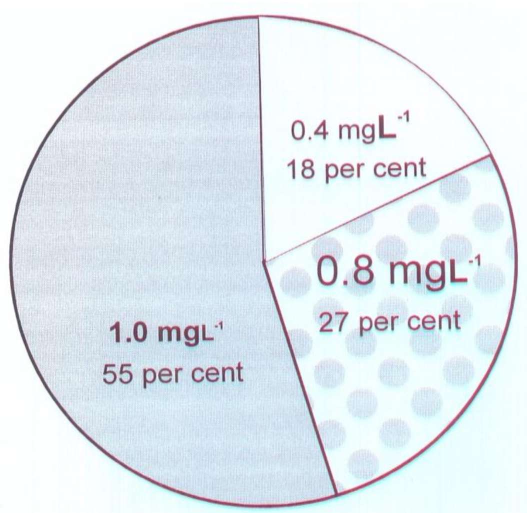

Figure 2: Percent mortality of fish in Iron (Fe) solution

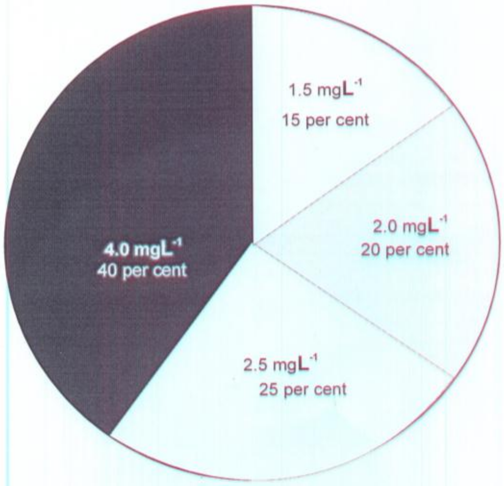

Figure 3: Percent mortality of fish in Lead (Pb) solution

3.2 Toxicity Studies

The LC_{50} obtained for Cu, Fe and Pb in this simulated study were 0.44, 0.96 and 2.85 mg/L, respectively. The order of toxicity of the heavy metals to tilapia fish was Cu > Fe > Pb.

3.3 Biological Productivity

Evidence of increased biological productivity was seen as the toxicity study lasted for 96 hours. This was most observable in the aquarium containing 2.65mg/l of lead.

This observation became only obvious in the aquarium containing 0.35 and 0.85 mg/l for Cu and Fe, respectively, as the time of the experiment was extended from four (4) to fourteen (14) days. The experimental set up showing gradation in colour as evidence of eutrophication is shown in Figure IV.

Figure 4: Evidence of eutrophication in different heavy metals solutions

Previous researches have shown that biological productivity can be affected by a number of factors and conditions which include:

3.3.1 Salinity

In China, *Balanus amphitrite* and *Tetraclita squamosa* have been used as biomonitors of cadmium, copper, iron, manganese and zinc in an attempt to investigate the differential availability of such metals in the coastal waters [11]. The results of metal concentrations in the different sampling locations were compared. Also results of metal concentrations in the two different species of crustacea were compared. Increase in accumulated body heavy metal concentration was observed for the effluent outfall in particular. In their study, there was no obvious association with salinity and accumulated body burdens of cadmium, copper and zinc in *B. amphitrite*, the pollution gradient caused by industrial contamination presumably over-shadowing any enhancement of bioavailability due to decreased salinity.

3.3.2 Heavy metal speciation

The behavioural and speciation of metallic species of Cu, Mn, Cd and Fe during estuarine mixing reveals that the physico-chemical forms in which the metals exist are more important than the total metal concentrations in the environment [12]. The study was focused on the variations of metals speciation in both dissolved phase and the suspended particulate matter during the mixing of fresh and salty water. These workers followed the method of Teiser et al. [13] which involved sequential extractions to partition metals into five fractions: 'exchangeable', 'bound to carbonate', 'bound to hydroxide', 'bound to organic matter' and 'residual'. They came out with the findings that environmental conditions such as pH, ionic strength and oxido-reduction processes can cause metals to become available and thus potentially toxic.

3.3.3 Effect of disease outbreak and biodiversity sustainability

Levels of heavy metals and organochlorides have been measured in the Habour Seal, *Vitulina* in Norwegian Waters by Skarre and co-workers [14]. The heavy metals under study in this work included mercury, cadmium, copper, selenium, arsenic and zinc. The seals were found dead or dying in Norwegian waters during the disease outbreak caused by a morbilli virus in 1988. The determinations were carried out using the liver tissue. From literature, they discovered that the concentrations of copper, zinc and arsenic obtained in their study represented normal physiological levels. They therefore concluded that the persistent organochlorines (OC) and mercury concentrations give little or no support to suggestions that OC and heavy metal pollution may have been directly involved in the observed death of the seals. They only may have added some additional stress to animals, during illness or starvation.

3.3.4 Temperature

The problems of dissipating waste heat differ from one location to another. Some receiving water temperatures in the USA and Britain have been reviewed as 30^0C and 24^0C, respectively [15]. Also, hot effluents from industrial processes and power generation have been seen to cause temperature increases in the receiving water of 10^0C or more. On the other hand, some effluents such as water pumped from deep mines or regulating reservoirs, have been shown to be colder than the receiving water [15]. In view of the prevalence of heated effluents, and of the potential importance of elevated temperatures indicated by laboratory studies, it is perhaps surprising that unequivocal examples of ecological damage by thermal pollution are rare [15]. A review of Hellawell [16] has cited no clear instances of any readily detectable adverse effect of elevated temperature such as on the ecology of receiving water. However, the review of Alabaster and Lloyd [17] based largely upon research in Eastern Europe suggest that temperature increases of between 2^0C and 8^0C do produce significant alterations in the biota of receiving water. Abel [15], states that in many circumstances, heated effluents are discharged to rivers, which are also polluted with organic or toxic matter and the effects of elevated temperature may be difficult to distinguish from other pollution effects.

4. Conclusion

The conclusion drawn from this work is that heavy metals support biological productivity in fresh water ecosystems and the degree differs from one metal to the other as was evident in the study. Regular bioassay, a test involving living tissues should be conducted in organisms or groups of organisms to determine the potency of any physiologically active substance of unknown activity. These tests have been used to ascertain effects such as toxicity, bioaccumulation, histopathology, growth rate, mutagenicity, embryo toxicity and teratogenicity.

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Justina I. R. Udotong was born in Ifuho in Ikot Ekpene LGA, Akwa Ibom State, Nigeria on 12 September 1960. She holds a Bachelor of Science (Hons) degree in Biochemistry from the University of Calabar, Calabar, Nigeria in 1985; Doctor of Philosophy (Biochemical Toxicology) from the same University in 2004.
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